Carbon Profiling: An Analysis of Methods for Establishing the Local Emissions Baseline

C Hamilton [1] J Kellett [1] & X Yuan [1 2]

School of Natural & Built Environments
University of South Australia
GPO Box 2471 Adelaide 5001
AUSTRALIA
E-mail: jon.kellett@unisa.edu.au

[2] Environmental Research Institute
Shandong University
No. 27 Shanda South Road, Jinan 250100
CHINA

Abstract

The prospect of state government driven carbon emission reduction targets brings with it the prospect of local target setting. Such targets will need to be based on good quality estimates of energy demand and greenhouse gas emissions along with viable assumptions about reduction potential at the local level. So there is a growing requirement for good quality emissions data at the level of local council areas.

Energy and greenhouse gas emissions baseline data are generally available at the national level in most developed economies and methodologies have been established at an international level by IPCC. In Australia greenhouse gas inventories are established at federal and state levels. However, more locally it becomes difficult to establish emissions profiles. Cities for Climate Protection has produced emissions profiles for a large number of local council areas in Australia, but this analysis often does not reflect local characteristics and conditions since it is derived from higher level data sets.

This paper examines a range of approaches which can be used to estimate local greenhouse gas emissions profiles. In particular it examines three alternative methods, using the City of Playford in South Australia and Manningham City Council in Victoria as examples. The aim is to test each of these approaches and compare the results in order to arrive at reliable emissions profiles which reflect local conditions. These can then be used as a basis for policy making and target setting with a higher degree of confidence in the likely outcomes than is presently possible.

Key words: Greenhouse gas, emissions profiling, carbon reduction, baseline

1. INTRODUCTION

In July 2007 the *South Australian Climate Change and Emissions Reduction Bill* became law. Mandated targets for green house gas (GHG) reductions are now enshrined in legislation, making South Australia the first place in Australia and one of a handful of places in the world, to legislate targets for GHG emission reductions. A key provision of the Act is to reduce by 31 December 2050 GHG emissions within the State by at least 60% to an amount that is equal to or less than 40% of 1990 levels as part of a national and international response to climate change (Government of South Australia, 2007). The Act makes specific reference to the need to set sectoral and interim targets to provide stepping stones on the path to its ultimate emissions reduction target. The Act further notes that the minister has the power and responsibility to determine the method for calculating GHG for the purpose of setting relevant 1990 levels (the baseline) and further to determine the method for calculating the reduction in any GHG emissions. The provisions of this new legislation present a number of challenges in their implementation. Central to these challenges is the issue of measurement. The enforcement of the Act and the achievement of sectoral and interim targets are only possible if both the emissions baseline and ongoing reductions can be measured. Furthermore, given the financial costs, resource inputs, commercial implications and behaviour change implications of the legislation, it is important that measurement of these key factors is as accurate and scientifically robust as possible. Community targets are specifically mentioned in the Act. An obvious approach to emission reduction measurement in respect of the community rests on using local council spatial areas as the basic unit for administration. There are a number of arguments for adopting this approach. Local Councils are accepted bases for data collection in respect of land use and property, which are major sources of GHG emissions. They also have resources and powers which they can employ in respect of new construction and existing properties as part of programs to ensure structural building standards and the broader sustainability of development. Furthermore, a Statewide emissions reduction program demands a degree of spatial equality in its implementation, which can be achieved in part by the allocation of sub targets to specific areas using local councils as both the spatial basis and implementation mechanism. Experience in the United Kingdom (UK), one of the few other places which have mandated emission reduction targets, suggests that this approach is considered equitable and useful by central government agencies. But a local council area based approach begs the critical question of whether the existing data sources are appropriate and sufficient to provide an acceptable level of accuracy on the measurement of both baseline emissions and ongoing emission reduction. Specifically, the problem of identifying an emission baseline for 1990 is key to the success of the Act. So too is estimation and political acceptance of a baseline level for the present day against which ongoing improvements can be set. This paper seeks to address the issue of baseline assessment on the presumption that it is a vital prerequisite to effective implementation of the South Australian Climate Change Act.

The aims and objectives of this paper are to:

- provide a summary of the literature related to methods being adopted internationally and in Australia for the assessment of baseline GHG emissions
- describe methods applicable at the local government level
- trial three carbon assessment methods in two contrasting local council areas namely, the City of Playford in South Australia and the Manningham City Council in Victoria
- evaluate the methods and data sets currently available to perform baseline assessments

2. ESTABLISHED METHODS FOR BASELINE EMISSIONS ASSESSMENT

2.1. Australia's Carbon Assessment Methods

Since 2004, GHG emissions for Australia have been calculated by the AGO according to methods outlined in the *AGO Factors and Methods Workbook* (AGO, 2006a) and the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks: States and Territories* (AGO, 2006b). The GHGs that are emitted by communities depend on the type of fuels that a community uses to provide energy for its activities, the type of wastes a community produces, the types of processes used to handle wastes and the types of industrial and commercial activities which are undertaken. Communities use energy for their day to day activities and consume products which have been manufactured or produced using processes that either emit GHGs directly or use energy that has been produced by processes that generate GHGs. Communities also produce wastes which require treatment and disposal. GHG emissions are calculated as a product of an activity level (eg fuel consumed) and an emission factor. In order to calculate GHGs the actual fuel consumption data should be obtained or estimated and the appropriate emission factor applied for each fuel. In Australia, emission factors have been developed for each type of fuel consumed for transport and other purposes eg home heating or commercial /industrial use and for each State emission factors have been developed for electricity consumption and natural gas consumption (AGO, 2006b). The Australian Bureau of Agriculture and Resource Economics (ABARE) have compiled data relating to fuel consumption by sector for Australia and for each State and Territory. These include categories of agriculture, mining, manufacturing, construction, electricity generation, transport, commercial and services, residential and a category of 'other' sectors. Using the ABARE data and State based emission factors the GHG emissions for each sector can be calculated at a State level for each type of fuel consumed.

The *Australian Greenhouse Inventory* (AGO, 2007) provides a summary of emissions from the energy sector which comprises stationary energy facilities, transportation (mobile combustion) and fugitive emissions from the handling of fuels. These emissions together accounted for 70% of Australia's GHG emissions (AGO 2007) with the stationary energy component alone comprising 50% of Australia's emissions. Of the remaining 30% of Australia's GHG emissions, agriculture contributed 16%, land use, land use change and forestry contributed 6%, industrial processes contributed 5% and waste contributed 3%. In addition to the reports produced by the AGO, the Australian Bureau of Statistics (ABS) undertakes surveys to ascertain attitudes to environmental issues and monitor trends that are taking place across states using a sample survey. Energy consumption practices, household and dwelling characteristics and the use of appliances and energy efficiency initiatives have been obtained and reported using this method. It should be noted that while surveys of environmental issues and trends are undertaken by the ABS each year, the focus is not always on energy.

2.2. Carbon Assessment Methods applicable for use at Local Government level

While inventories of GHG emissions have been developed for the whole of Australia and for States and Territories, compiling fuel consumption and emissions within each sector and below the State level is more problematic (AGO, 2006b).A number of approaches have been developed and applied to the assessment of GHG emissions at a local spatial area level. Obtaining reliable and relevant data at this level is difficult due to confidentiality. A method has been developed by the ICLEI CCP program (CCP, undated) to enable local government agencies undertaking GHG reduction initiatives within their own council operations to estimate the emissions arising within their community and thereby provide a baseline for their community to assess itself against while implementing initiatives to reduce GHG emissions across its area of responsibility and influence. The CCP database also has ability to calculate projections for energy use and GHG emissions for each sector. These are based on ABARE state based projections for population and businesses. Future employment numbers are not projected but use the base year numbers.

Bennett and Newborough (2001) observed that in the UK, energy consumption data tended to be available at either a macro (international or national) level or a micro (individual establishment or residence) level with very little reliable data collected at the community level. The usefulness of macro level consumption data in bringing about behaviour change was considered to be low and it was considered that individual businesses or households would respond more favourably when they could see consumption levels at the community level. The collective response of a city, town or urban district was considered to promote the greatest ownership of energy-saving emissions reduction initiatives. They developed a method that involved the following:

- Divide the area into a series of key sectors – ie residential, industrial, retail, government agency.
- Divide each sector into sub-sectors and continue to subdivide until the data is no longer available.
- Collect data.
- Identify gaps where data is missing and undertake specific studies (data collection) from local sources to fill gaps.
- Aggregate the data for the whole area.

In recognition of the problems inherent in the large scale data survey which can result from the above approach Grant and Kellett (2001) described a method for undertaking the baseline assessment of energy use in a study of Conisbrough and Denaby area of the UK. Their method was similar to Bennett & Newborough's but avoided large scale survey and data collection by relying on pro rata national data and sample surveys where necessary. Shaw (2004) then outlined a method for undertaking a baseline energy and GHG emissions assessment for Sheffield in the UK using a hybrid of the two above approaches. The hybrid approach adopted used the following method–

- Conduct an indicative energy assessment based on both national data for an area and local data for each sector where available.
- Produce energy consumption ratios based on numbers of households, numbers of people employed, the floor area of buildings and number of vehicles and journeys.
- Produce estimates of final energy consumption per sector and fuel type.
- Calculate greenhouse emissions using standard emission factors for each fuel consumed.

In Australia there have been a number of studies conducted at the neighbourhood scale. Perkins (2002: 2007) undertook two studies of life cycle energy used for housing and transport for samples of households in metropolitan Adelaide. In the first study operational energy consumption was obtained from the 212 households in the case study areas in the form of electricity and gas bills, wood and oil use data. Travel diaries were used to record actual trips undertaken and mode of transport used. Perkins also calculated embodied energy as well as operational energy using actual house plans and construction materials information. Troy et al (2003) undertook a study of embodied and operational energy consumption across the metropolitan area of Adelaide. Electricity and gas consumption of households was obtained directly from the utilities for a sample of 30 houses in each of six case study areas. The case study areas were chosen to be representative of different stages of development in the spatial layout of Adelaide's metropolitan area. The study also estimated the energy consumed in the transport task for each study area .using a combination of Census data for private vehicle and bus travel (Troy et al 2003: 29). Oliphant (2004) conducted a study of a small inner-city ecologically sustainable development in Adelaide, and compared this to studies undertaken by the University of South Australia at the Mawson Lakes subdivision in the northern suburbs of metropolitan Adelaide (Saman and Mudge 2003). The studies obtained energy use (gas and electricity) at the household level directly from the household meters and reported GHG emissions related to these levels of consumption. The emissions were reported for six homes in Mawson Lakes, a number of homes in the inner city development and the energy used for a network of homes at Mawson Lakes. In this case transport energy use was not included. Finally, Pullen et al (2006) conducted a study of operational and embodied energy in twelve case study areas of metropolitan Sydney during 2004. Annual operational energy data for gas and electricity use was collected directly from energy retailers but transport energy use was not included.

Ideally the assessment of GHG emissions for a community would collect actual energy use and waste generation data for all sectors of the community within a local government area. While this can and has been undertaken on a small scale generally using a sample of the population, undertaking this on a local government scale is problematic due to confidentiality of energy consumption information and the considerable time required to collect and validate the data. The evidence suggests that ABS surveys, Local Government data sets and Utility Company data provide the most reliable sources for assessment of local area energy and GHG baselines, but these suffer restrictions from irregularity, incompleteness or confidentiality. In the absence of detailed data alternative approaches are necessary to estimate baseline energy demand at the Local Government area level.

3. CARBON ASSESSMENT METHODS TRIALLED

As part of a larger Australian Research Council (ARC) sponsored project investigating methods for implementing transition to carbon neutrality at a community level, three approaches to determining baseline energy demand and greenhouse gas emissions were compared using project partner Local Government areas, namely the City of Playford in South Australia and at Manningham City Council in Victoria. The methodology adopted builds on the approach developed in the studies described above. The first was a top-down approach, the second a hybrid bottom-up approach and the third used existing information and projections provided by the Cities for Climate Protection (CCP) program. The aim was to test the validity of the three approaches by comparing the relative sectoral breakdown and quantity of energy demand and related greenhouse gas emissions as well as the total energy demand and greenhouse gas emission estimates.

3.1. Approach 1 – top down.

In this method the GHG emissions related to energy consumption for residential, industrial, commercial and transport sectors for each of the City of Playford in South Australia and the Manningham City Council in Victoria were calculated as a pro rata of State level statistics based on the population. The energy consumed and GHG emissions for each of these local government areas was determined on a pro rata basis from the state figures for each sector and reported as per capita energy use, annual total energy use and annual greenhouse emissions. The assessment of the emissions from waste was determined on a pro rata basis from the state emissions for waste.

3.2. Approach 2 – hybrid bottom-up.

A hybrid approach similar to that described by Shaw (2004) was used and is described as follows:

- Define the boundary of the area
- Divide the area into sectors including residential, commercial, industrial, agricultural and transport
- For each sector determine the level of information available to calculate fuel consumption
- Obtain energy consumption, dwelling numbers, size of dwellings (number of rooms), population, vehicle numbers, vehicle type, fuel used at sectoral or local government level or if available at a lower level such as suburb or postcode
- Obtain emission factors (EFs) for each of the fuels consumed - relevant to the jurisdiction
- Obtain information about the area of land used for agriculture, type of crop, number of animals
- Obtain data on waste volumes/weight produced by type of waste, volumes/weight of waste recycled, waste disposed and how disposed
- Obtain emission factors for waste disposed to land fill

In Australia, the ABS collects and publishes data for some of these. However for other information such as the area of dwellings and business establishments this data is not readily available for local government areas. Similarly the disaggregated fuel consumption figures at the local government level are also not readily available. The AGO provides information on emission factors for fuels at the State level. The ABS reports waste management at the state level. However the local government agency is more likely to hold figures on annual waste produced by type and how it is disposed of or recycled as the provision of waste management to a community is generally a responsibility of local government in Australia. For the residential sector for City of Playford it was resolved to use the average per capita energy consumption as recommended by Oliphant (2003) who observed that the number of people in a dwelling was of greater significance to overall energy consumption than the size of the dwelling (floor-space) or number of rooms.

The energy use of households in Manningham was calculated using two methods

- The first method (2a) used household and per capita electricity consumption data from meters for some of the suburbs within Manningham during 2003 and reported by AIUS (AIUS, 2005). The amount of other fuels used was calculated assuming that the proportion of all fuels was the same as the state figures for 2004/05 (ABARE 2006).
- The second method (2b) used the average household energy use for 2001 from the *Energy for Victoria* publication (DOI, 2002).

For commercial and industrial premises there was an attempt to calculate energy use by area of floor-space using intensity from studies undertaken in the United States and reported by the AGO. However the information available for the City of Playford through the SA Government Land Services Group valuation database proved unreliable and it was resolved to use employee numbers rather than area of floor-space.

3.3. Approach 3 – projection from CCP data.

This approach took the energy consumption and GHG emissions results from each assessment for each of the Residential, Commercial, Industrial, Transport and Waste sectors for each local government area as determined by CCP. It also used the projections made by the CCP program for the Year 2010. A line of best fit was applied. Based on this straight line relationship the energy consumption and emissions at 2006 for each sector for each local government area were calculated.

4. RESULTS OF THE TRIAL FOR THE THREE APPROACHES

4.1. City of Playford

The City of Playford is a local government area located approximately 30 km north of Adelaide and forms part of the northern metropolitan area of Adelaide in South Australia. It is approximately 346 sq km in area and consists of 35 suburbs. It contains the Munno Para area first established in 1853 and the city of Elizabeth, designed and built in the 1950s to provide housing and industry for an influx of immigrants from Europe after the Second World War. The City of Playford contains 19,000 ha of prime horticultural areas on the Northern Adelaide Plains and 7,150 ha of the Mount Lofty Ranges within its boundaries. There are 2 district retail centres, 9 neighbourhood retail centres, 12 local retail centres and 3 rural townships also within its boundaries. Industry is located mainly in the Elizabeth South suburb where the General Motors Holden automobile manufacturing plant is located and in the Elizabeth West suburb. The population usually resident in South Australia was 1,514,337 at 8 August 2006 (ABS, 2007a). The population of Playford usually resident at that time was 70,011 which equated to 4.62% of the state's population.

Approach 1 – top down.

The annual per capita energy use, total energy use and associated GHG emissions for the City of Playford using Approach 1 were calculated on a per capita pro rata basis from data for the whole of South Australia (ABARE, 2006) and (ABS, 2007b) and are summarised in Table 1. According to this approach the industrial and transport sectors used the most energy (43% and 34% respectively) while the residential sector used 13%. The GHG emissions likewise were dominated by the industrial sector with 38% of emissions followed by the transport sector (25%) and the residential sector (19%). Emissions from agriculture were included as agricultural activity (mainly horticulture) is undertaken in the City of Playford area.

Approach 2 – hybrid bottom up.

The results of this approach are summarised in Table 1. This approach resulted in approximately 50% of all of the energy used and 45% of the carbon emissions for Playford being due to industry with the manufacturing industry alone contributing 95% of the energy used by this sector. The next highest energy user is the transportation sector at 32% of energy used and 26% carbon emissions and the residential sector with 11% of energy used and approximately 18% of carbon emitted.

Approach 3 – projection of CCP data.

This approach took the 1995 baseline GHG emission assessment, the 2001 reassessment and sector by sector projections to 2010 from the City of Playford and applied a linear pro-rata back to 2006. The City of Playford, a CNC project Partner, provided the information from its CCP program assessment and projections. These have been reproduced here in Table 1 together with the calculated figures for the Year 2006. Using this approach the industrial sector used 45% of energy and accounted for 40% of carbon emissions, while the transportation sector used almost 36% of energy but contributed only 20% of carbon emissions. The residential sector accounted for 13% of energy but contributed 24% of carbon emissions.

4.2. Manningham City Council

Manningham City Council is located 12 km east of the Melbourne Central Business District and is bounded on the north and west by the Yarra River and the Koonung Creek to the south. It contains 1200 ha of parks, gardens and reserves within its total area of 114 sq km. Land use is mainly residential with all or part of 11 suburbs within its boundaries. It contains 1 regional and 1 sub-regional retail centre and 30 local retail centres. Its businesses are mainly small commercial enterprises with one third home-based (Manningham City Council, 2007). The population of Victoria was 4,932,422 at 8 August 2006 (ABS, 2007b). At the same time the population of Manningham was 109,915 which was 2.23% of the state's population.

Approach 1 – top down.

The ABARE figures for energy use by sector for Manningham were calculated as a pro rata of state figures for 2004-05 for Victoria (ABARE 2006). GHG emissions were calculated using the *AGO Factors and Methods Workbook* (AGO, 2006a). The GHG emissions for waste were calculated using the 2005 GHG inventory report for Victoria (VGGI, undated). The per capita energy use, total energy use for Manningham and associated GHG emissions for various sectors are summarised in Table 1. Using this approach it can be seen that the transport sector used 39% of the energy followed by industry which used 34% and the residential sector 19%. The commercial sector used 8% of the energy according to this approach. The resultant GHG emissions based on the per capita approach showed that the greatest contribution was made by the industrial sector which generated 38% of the GHG emissions followed by the transport sector with 23%. The residential sector generated approximately 20% of GHG emissions and the commercial sector 15%.

Approach 2 – hybrid bottom up.

The transport sector comprising the vehicles registered in Manningham together with the transport & storage industry used the most energy (almost 55%) according to this approach, followed by the residential sector which used 33%. The industrial and commercial sectors used 7% and 6% respectively. The GHG emissions however were produced mainly by the residential sector (44%) and the transport sector (30%). According to this approach the commercial sector generated 13% of the GHG emissions for Manningham despite its lower energy use.

Approach 3 – projection of CCP data.

This method took the results for Manningham determined by the CCP program then applied projected increases or decreases sector by sector. For the Manningham City Council the CCP program has made predictions for the energy use in 2010. Using a graphical approach a straight line was drawn through data for 1996, 2001 and 2010. Values for energy use and GHG emissions for 2006 were estimated from the straight line.

Table 1. Summary of energy consumed and carbon emitted from the application of three different carbon assessment methods across two different local government areas

	Total	Residential	Commercial	Industrial	Transportation	Waste	Agricultural
Playford South Australia							
Method 1							
Energy PJ	12.23	1.63	0.82	5.25	4.12		0.41
%	100	13	7	43	34		3
Carbon emissions Mt CO2-e	1.19	0.23	0.14	0.45	0.3	0.04	0.03
%	100	19	12	38	25	3	3
Method 2							
Energy PJ	9.3	1.0	0.38	4.66	2.98		0.24
%	100	11	4	50	32		3
Carbon emissions Mt CO2-e	0.96	0.17	0.07	0.43	0.25	0.02	0.02
%	100	18	7	45	26	2	2
Method 3							
Energy PJ	8.48	1.10	0.50	3.85	3.03		nc
%	100	13	6	45	36		
Carbon emissions Mt CO2-e	1.05	0.25	0.11	0.42	0.21	0.06	nc
%	100	24	10	40	20	6	
Manningham Victoria							
Method 1							
Energy PJ	19.28	3.65	1.587	6.54	7.51		nc
%	100	19	8	34	39		
Carbon emissions Mt CO2-e	2.34	0.48	0.35	0.89	0.53	0.09	nc
%	100	21	15	38	22	4	
Method 2a							
Energy PJ	11.76	3.87	0.67	0.81	6.41		nc
%	100	33	6	7	54		
Carbon emissions Mt CO2-e	1.16	0.51	0.15	0.12	0.35	0.03	nc
%	100	44	13	10	31	2	
Method 2b							
Energy PJ	11.16	3.27	0.67	0.81	6.41		nc
%	100	29	6	7	57		
Carbon emissions Mt CO2-e	1.03	0.38	0.15	0.12	0.35	0.03	nc
%	101	37	15	12	34	3	
Method 3							
Energy PJ	9.8	2.95	1.0	0.75	5.1		nc
%	100	30	10	8	52		
Carbon emissions Mt CO2-e	1.12	0.45	0.2	0.092	0.35	0.03	nc
%	100	40	18	8	31	3	

Note that some percentages may not add up to 100% due to rounding

5. CONCLUSION

The analysis of Playford and Manningham demonstrates a number of key aspects which serve to inform future studies. The hybrid methods (Approaches 2 and 3) resulted in significantly lower energy consumption and carbon emissions than the top down method based solely on pro rata population (Approach 1). These hybrid methods better reflect the actual number of households and employees and the type of business being conducted as well as data from studies conducted locally about energy use. The key differences relate to energy consumed in the industrial sector and are most clearly noted in the case of Manningham. Here, the energy consumed according to the top down method, was 34% of the total for the area with GHG emissions amounting to 38% of total emissions. According to the hybrid methods the industrial sector used only 7-8% of energy and contributed 8-10% of GHG emissions. In the case of Playford the top down method resulted in 43% of the energy use being attributed to the industrial sector with 38% of the GHG emissions. The bottom up- hybrid method resulted in 50% of energy used and 45% of the GHG emissions while the CCP method resulted in 45% of energy used by this sector and 40% of GHG emissions. Since Manningham represents a situation where the proportion of industry is lower than the State average and Playford represents the reverse, these results are entirely consistent with expectations. They nevertheless do not provide us with reliable actual quantities of either energy demand or GHG emissions. The hybrid methods differ in how they calculate residential energy use and in how the energy used by the transport sector is calculated. Approach 2 used the study by Oliphant (2003) to determine the electricity and gas use for households of varying size in Playford. For Manningham two different bases for calculating total energy used by households were employed, one based on a sample of actual data for electricity, the second on pro rata Victoria data. Different proportions of fuel use were applied. There was a broad agreement between approaches 2 and 3 for residential energy demand in Playford, but less so between these methods as applied in Manningham, suggesting that the attempt to disaggregate domestic fuel use here had complicated the picture. Not surprisingly the GHG outcomes differed more significantly. The assumptions made about consumption of fuels other than electricity for Method 2a need further assessment. Again the conclusion must be that none of these methods provides us with an accurate quantified explanation of energy use and GHG emissions in the residential sector. After Industry, transport proves to be the next most significant sector in all cases. There is broad agreement between methods 2 and 3. The higher estimates derived from method 1 probably reflect a critical problem in the allocation of transport energy on a spatial basis, namely that many, especially long distance trips are difficult to assign to specific locations. Thus much long distance transport, especially in the freight sector, which is included in state wide statistics, is lost when we try to allocate transportation energy to specific locations. Furthermore, the Transport & Storage Industry consumption figures used comprised energy used per employee for all of the road, rail, air and sea transport industry sectors. This may lead to an overestimation of energy used in this sector even using methods 2 and 3.

When we consider the total energy and GHG profile for the Local Government areas in question we can immediately observe a large variation in the overall totals deriving from the three methods. For Playford the total ranges from 12.23 PJ to 8.48 PJ. For Manningham the range is 19.8 PJ to 9.8PJ. The evidence suggests that the lower estimates are a more accurate reflection of reality since they are built from the bottom up using actual data wherever possible. However the large discrepancies between methods beg the question of why the top down approaches are such overestimates. They also beg questions about future target setting under legislation such as the *SA Climate Change and Emissions Reduction Act.* The relative proportions of energy use and GHG emissions produced by all the methods broadly match the national sectoral energy breakdown, suggesting a degree of confidence can be drawn from all approaches. However when we consider the objective amounts of energy or GHG then the major discrepancies found across the various methods suggest that there is substantial work needed before estimates that are acceptable to all prospective parties can be achieved. .

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